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Data Acquisition Applications for Long Duration Electromagnetic Launcher Experiments

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Investigation of the basic physics associated with Electromagnetic Launcher (EML) operation requires accurate measurement of a number of diverse phenomena. Monitoring and recording EML phenomena during operation over relatively long time frames places unusual demands on a Data Acquisition System (DAS). While the sampling rate requirement is modest by DAS standards of today, the combination of the sampling rate and the number of events to be monitored presents challenges. This paper describes the evolution of a data acquisition approach in use for basic research in the EML area, discusses data acquisition capabilities and requirements, and presents examples of the data that has been obtained using this approach.

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PREFACE

This report documents research conducted using a battery charged capacitor power supply to produce long duration power pulses for rapid fire Electromagnetic Launcher (EML) burst fire experiments. Specifically, this paper discusses the data acquisition system that has been developed for the analysis of long duration EML experiments and the unique problems associated with them and how they were solved. This technical report was presented at the 6th Electromagnetic Launcher Conference in Austin, TX 28 April to 1 May 1992.

This work was funded by the Electromagnetic Launcher Technology Branch (WL/MNSH) of the Analysis and Strategic Defense Division of the Wright Laboratory, Armament Directorate at Eglin AFB, FL under the Kinetic Energy Weapons program of the Strategic Defense Initiative. Mr. James B. Cornette and Mr. Mark W. Heyse from WL/MNSH and personnel from Science Applications International Corporation (SAIC) in Shalimar, FL performed the work during the period March 1991 to April 1992 at Eglin AFB FL 32542-5000.

Data Acquisition Applications for Long Duration Electromagnetic Launcher Experiments

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Abstract - Investigation of the basic physics associated with Electromagnetic Launcher (EML) operation requires accurate measurement of a number of diverse phenomena. Monitoring and recording EML phenomena during operation over relatively long time frames places unusual demands on a Data Acquisition System (DAS). While the sampling rate requirement is modest by today's DAS standards, the combination of the sampling rate and the number of events to be monitored presents challenges. This paper describes the evolution of a data acquisition approach in use for basic research in the EML area, discusses data acquisition capabilities and requirements, and presents examples of the data which has been obtained using this approach.

I. Introduction

EML diagnostic techniques which include: instrumentation, signal conditioning, signal transmission, calibration, and data acquisition have been addressed to some extent by many EML researchers. In fact, workshops focusing on these topics for several EML subsystems have detailed the requirements and approaches commonly used [1, 2]. Where data acquisition is concerned, the most commonly used approach has been the storage oscilloscope. The storage scope offers the advantages of built-in signal conditioning, high resolution for monitoring relatively fast pulse events and portability. This combination of features provides a degree of user friendliness which has made the storage scope the device of choice. The principle disadvantages have been post experiment data manipulation for analysis as well as limited memory capacity. Both of these disadvantages are magnified as the number of signals to be monitored or the duration of the experiment increases.

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Data acquisition for long duration experiments involving multiple EML discharges was first approached using a combination of the traditional storage scope set-up with a separate set of scopes for each discharge and an FM tape recorder [3]. While this approach met the needs of these early experiments (1984-85), which were typically viewed over a two second window, real time correlation of the various signals during analysis, post experiment processing and archiving of the data was hampered by the number of discrete instruments used and the fact that they were not centrally controlled. Follow-on approaches used custom combinations of waveform digitizers and minicomputer systems to address these issues. Early digitizer memory limitations again resulted in large numbers of instruments and a significant software development task. The potential advantages in data processing and archiving offered by evolving digitizer technology provided an attractive approach for future experiments which would be more demanding. For these reasons the Electromagnetic Launcher Technology Branch of Wright Laboratories (WL/MNSH) has pursued the application of digitizer technology in support of basic research conducted with the Battery Powered Capacitor and the CHECMATE EMLs where high data throughput is required.

II. Requirements

Data collection for EML research is an activity that is complicated by both the diverse nature of the data to be acquired and the duration during which this occurs. Fig. 1 illustrates the diversity of typical signals that are monitored in EML research. These signals can be generally grouped in two categories; burst and event. Burst signals are those which are monitored for the complete experiment duration where as event signals are focused on a discrete event within the overall experiment. This division is brought about by the conflicting requirements for sampling rate and sampling duration of the signals concerned.

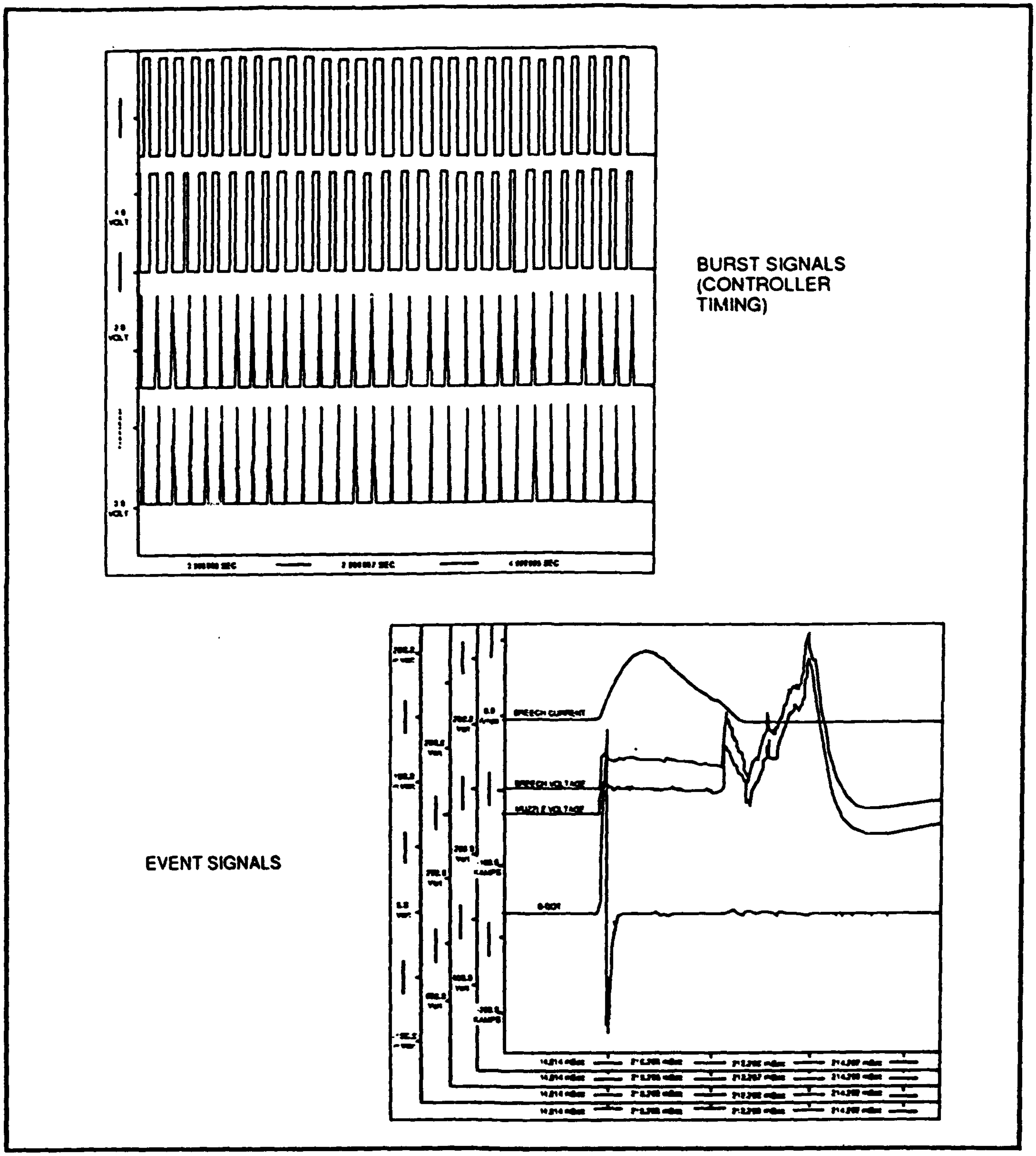

Fig. 1. Typical Signals Monitored for EML Research

Event signals are potentially the most demanding in terms of storage and handling requirements. Signals in this category result from transient phenomena that occur in micro to millisecond time frames, usually during the EML discharge. These rapid events require high sampling rates, usually hundreds of kHz, to provide adequate waveform resolution. Maintaining such high sampling rates for a long duration, several seconds, experiments require large data storage capacity. For example, continuous sampling at 200kHz (5 microseconds/point) for a typical five second experiment requires 1 megabyte of memory. A typical EML experiment requires approximately 20 such signals be monitored as a minimum.

Burst signal sampling rate requirements vary over a broader range than do event signals. Generally, signals in this category result from phenomena that occur over relatively long time frames, hundreds of milliseconds to seconds. Usually these signals are associated with EML support systems such as pneumatic and power subsystems where tens of kilohertz sampling will provide adequate waveform resolution. However, depending on the scale and scope of the experiment, hundreds of signals in this category may need to be monitored for a single experiment. In addition, some burst signals, power supply switching and control signals for example, may require sampling rates as high as the event signals. The net result is yet another large data processing and storage requirement.

Table I summarizes the event and burst signal requirements that are typical of the EML experiments conducted with the Battery Powered Capacitor and CHECMATE EMLs. Experiments of two to seven seconds in duration are routinely conducted with these EMLs.

The combined effects of sampling rate, sampling duration, and number of signals to be monitored not only result in very large data storage requirements they also directly effect the rate at which research can progress. Post experiment processing of large quantities of data to facilitate analysis can be a significant overhead burden. Data processing hardware requirements and more importantly custom software development requirements increase at least linearly with the quantity of data. As the sophistication, duration, and scale of EML experiments increase simultaneously the need to minimize these impacts becomes more and more important. The preferred approach to satisfying the data acquisition requirements then must address achieving the desired waveform resolution and at the same time minimize the overall volume of data.

TABLE I.
EVENT AND BURST SIGNAL REQUIREMENTS

Signal	Category	Number of Signals	Signal Duration
B-dot	Event	10-20	.1-1msec
Breech Current	Event	2	1-4msec
Breech Voltage	Event	1	1-4msec
Muzzle Voltage	Event	1-4	1-4msec
Heat Flux	Burst	3	1-7msec
Bore Pressure	Event	3	1-4msec
Capacitor Voltage	Burst	4-16	1-7msec
Control	Burst	5-10	1-7msec

III. CAPABILITIES

The data acquisition approach presently in use for EML basic research by MNSH consists of a fully integrated waveform digitizer DAS. In it's present configuration 32 input modules provide 56 digitizer channels which are centrally controlled by a 386 PC. Characteristics and features of this DAS are summarized in Table II. The key features in terms of the EML research data requirements are it's ability to sample high rate signals in a segmented fashion while maintaining a continuous time base, expansion potential, and level of integration.

Overall data volume is reduced considerably by the DAS's ability to acquire high speed data in segments. Fig. 2 shows a one second window of an EML experiment which illustrates the efficiency of this approach. The upper plot shows several waveforms sampled on a continuous basis over the duration of

TABLE II.
DAS CHARACTERISTICS AND FEATURES

- 386/20 MHz PC Controller
  - 4080 Digitizer Capacity
  - Channel Configurations Stored & Recalled
  - Built-in Interactive Math Functions
  - Independent & Bus Triggering
  - On Screen Quick Look Capability
- 8 Four Channel 1 MHz Digitizers
  - 1-2-4 Channel Configurations
  - 256k Memory (Expandable to 1 Meg)
  - 1024 Segments With Separate Timebases
  - 3 Digitizing Rates per Segment
  - 30mV - 12 V Input
- 8 Single Channel 2 MHz Digitizers
  - 1 Meg Memory
  - 30mV - 12 V Input
- 16 Single Channel 10 MHz Digitizers
  - 1 Meg Memory
  - 30mV - 120 V Input

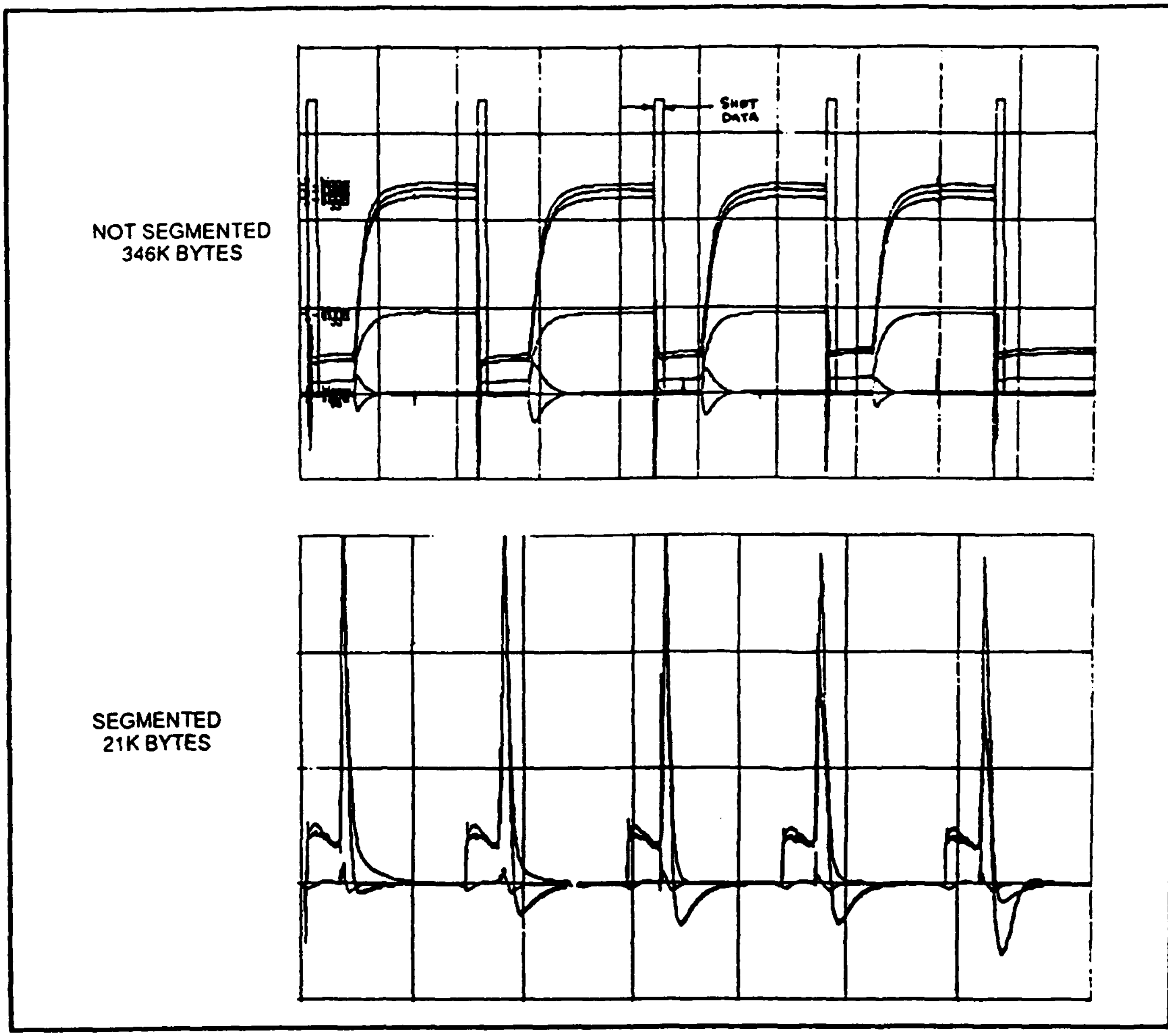

Fig. 2. Segmented Data Acquisition

the experiment while the lower plot shows the same signals sampled in segments. This feature allows high sampling rate data acquisition over user specified windows which are small compared to the overall experiment. Data is not acquired during the time between the windows, however, a continuous time base is maintained. Using this approach has resulted in an order of magnitude reduction in the data storage requirements for event signals.

Input capacity of the DAS is expandable to 4080 input modules which would provide over 16,000 data channels. In addition, further capacity can be achieved by using another feature of the DAS. Each segment, as discussed above, can be divided into three zones and separate sampling rates can be specified for two zones. In this way high rate sampling can be more narrowly focused.

The DAS system includes both hardware and software to provide a high degree of overall integration. A 20 MHz 386 personal computer controller is interfaced with the digitizers. Pre-experiment channel setup is accomplished centrally via the controller and provision is made for storage and recall of all channel configurations. Built-in interactive math functions such as differentiation, integration, and smoothing are combined with an on-screen quick look capability to facilitate post experiment data analysis.

IV. Data

Fig. 3 shows some event data typical of the experiments conducted with the Battery Powered Capacitor EML. Note that the data time line is not continuous. Each discharge into the EML is windowed to only the time of interest. Here, a typical experiment consisting of 30 events is shown with eight of the 26 event signals recorded superimposed on the same plot. The sampling rate used to monitor these signals was 143 kHz. The total duration of this experiment was 6.6 seconds. If data had been acquired on a continuous basis approximately 1 Mbyte of memory would have been needed for each channel. Segment times of 14.7 msec were used which only required 63 kbytes of memory per channel.

The expanded plots in Fig. 3 provide an indication of the resolution and nature of the data embedded within each event. These expanded sections were selected from random launch events. The EML current rises to a peak value of approximately 200kA in about 1ms. From the muzzle voltage trace, we can see the voltage rises until the plasma armature ignites and then drops to a relatively constant armature voltage during acceleration. After launch package exit, the voltage rises again. The B-dot data shows the progression of the armature down the bore.

B-dot signals present one of the more demanding data acquisition requirements. One application of the B-dot is to sense the position of the EML armature. As the speed of the armature increases so does the sampling rate needed to maintain the desired resolution. Fig. 4 shows an example of B-dot taken during recent experiments with the CHECMATE EML. Seven of the 19 B-dot signals sampled during this experiment are shown superimposed on the same plot. One pulse from the first event is expanded to more clearly show the waveform resolution. These signals were sampled at a 1 MHz rate over a 4 msec segment for each of the two events. The total memory required per channel was approximately eight kbytes. One Mbyte of memory would have been required to continuously sample at this rate over the duration of the complete experiment.

V. Conclusion

The data acquisition approach described in this paper provides the required performance for long duration EML research experiments. Integrated DAS systems which employ digitizer technology successfully address present waveform resolution and data processing demands with considerable reserve capacity for the future. Full capacity of the present DAS configuration with respect to throughput and data storage has not been required to date in a single experiment. However,

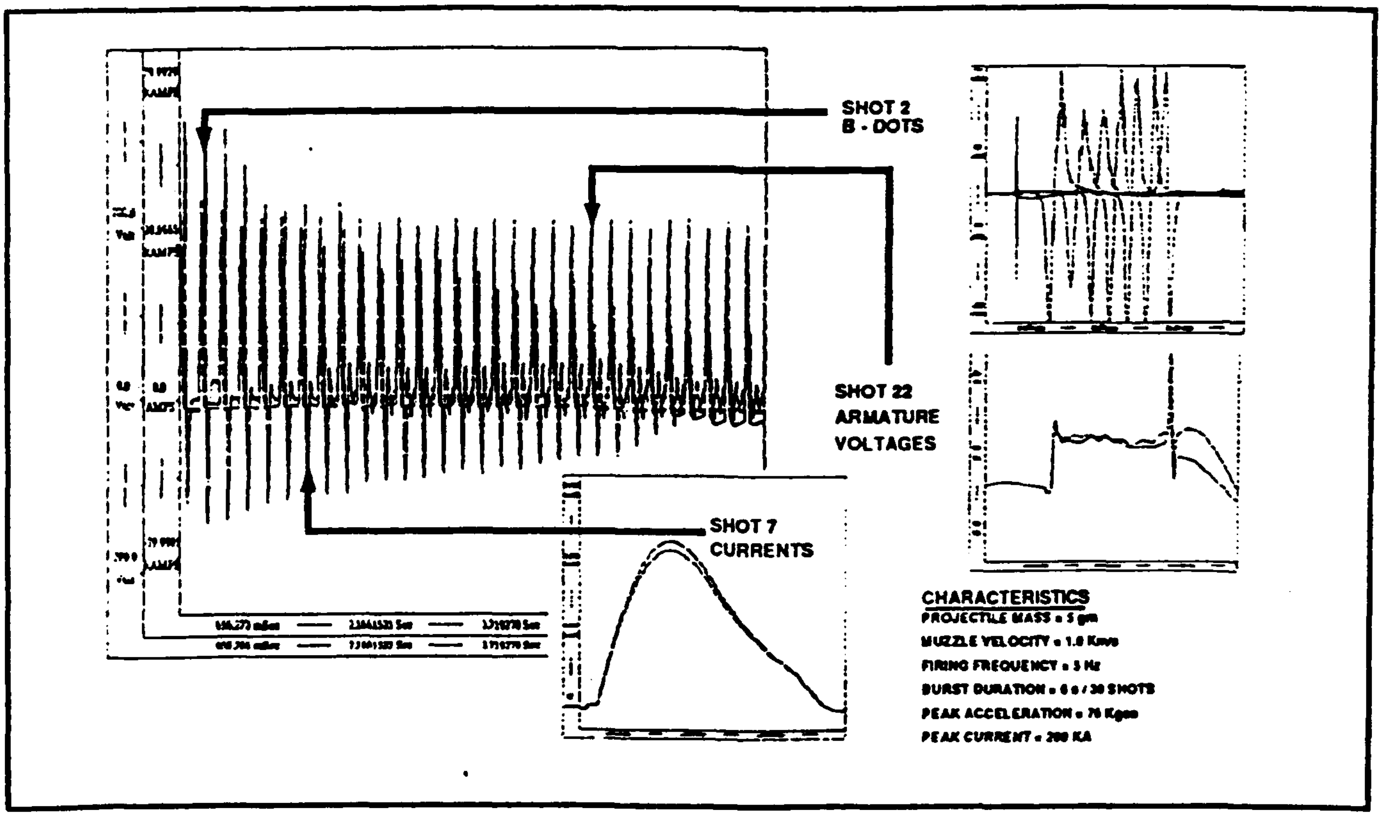

Fig. 3. Battery Powered Capacitor EML Data

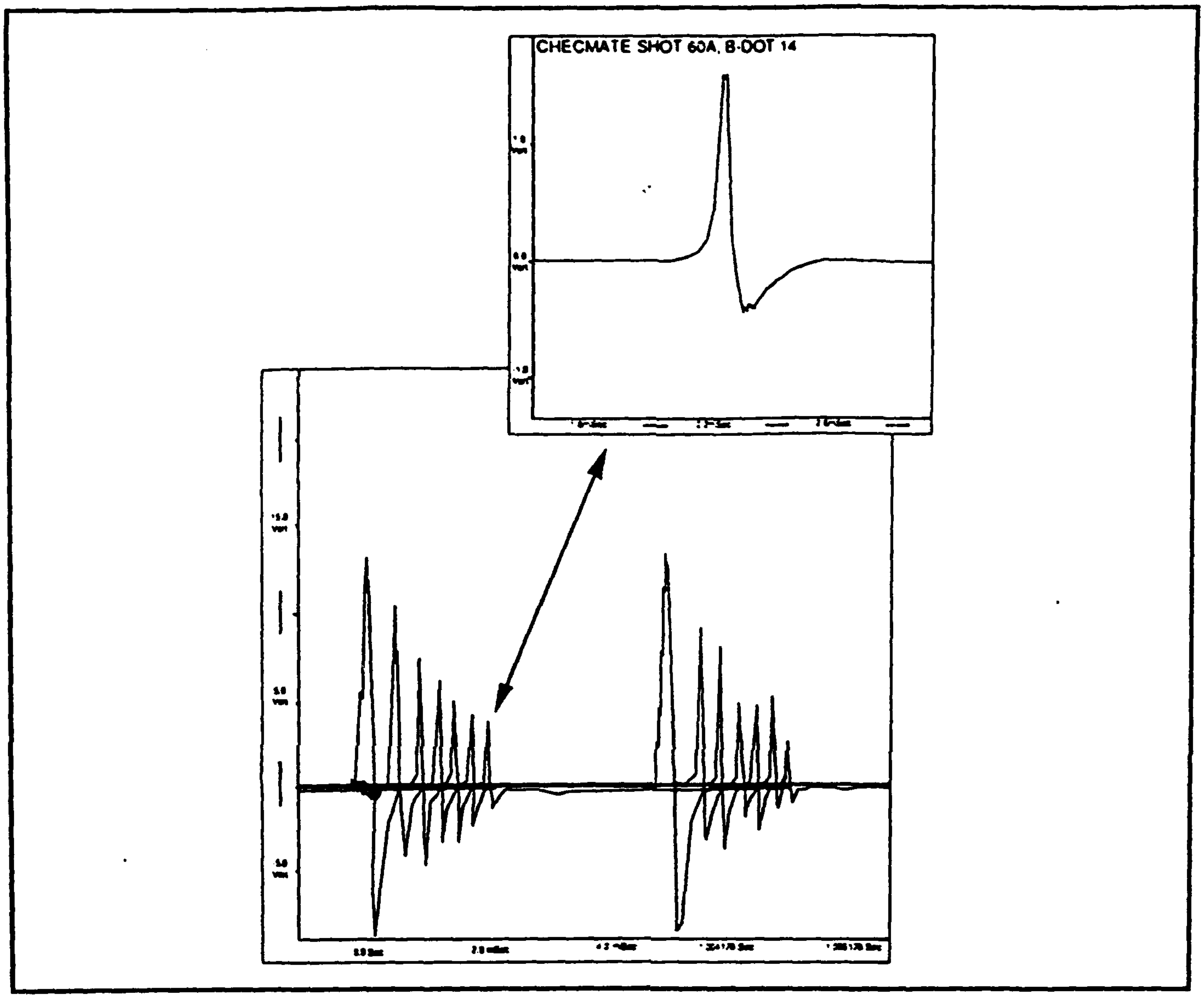

Fig. 4. CHECMATE EML Data

as the duration and scale of these EML experiments increase in the near term it is anticipated that all of the capabilities offered in the present DAS, to include segmenting with multiple sampling rates, will be used.

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